

Lidar Development

Weather Accident Prevention (WxAP) Annual Project Review

Hampton, Virginia, Radisson Hotel May 23-25, 2000

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Overview



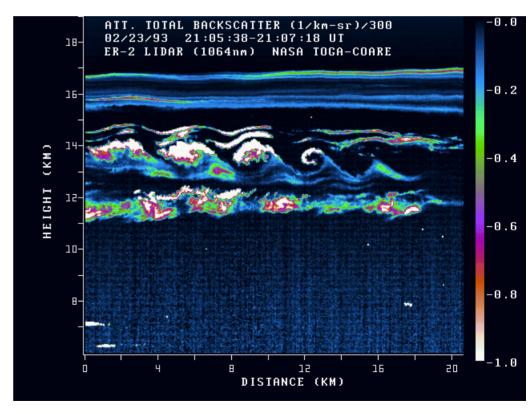
- Background information
- Technical accomplishments to date
 - algorithm development and performance simulation
 - flight test activities
- Plans





Turbulence Initiators

- Convective Storms (within and as far as 40 miles away from visible clouds in clear air)
- Jet Stream (at confluence of multiple streams and near boundaries)
- Mountain Wave (upward propagating from disturbances near the surface)



Localized "events" like these are extremely difficult to reliably forecast



Turbulence Product Development Team Objective



- Develop Means of Achieving Reliable Tactical Warning
 - Provide Timely Warning to Deviate or to Institute Cabin Safety
 Measures
 - Provide Real-Time Alerts to AWIN Network

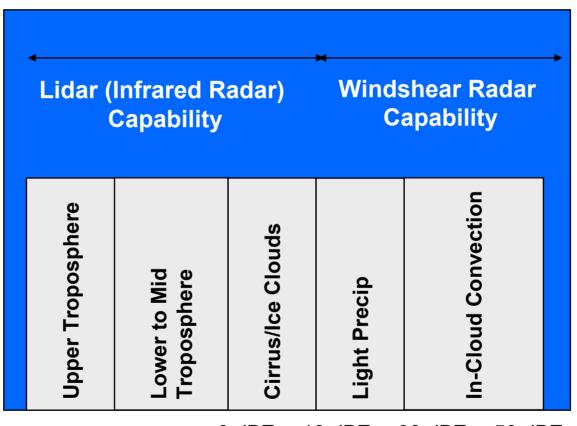


Complete Detection Capability Provided through Dual Wavelength Radar



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Objective:
Develop a robust detection capability that spans the full range of turbulence environments



0 dBZ

10 dBZ

30 dBZ

50 dBZ

X-Band Radar

Lidar units

 $-100 dB\beta$

 $-80 dB\beta$

-60 dB β

 $-40 \text{ dB}\beta$



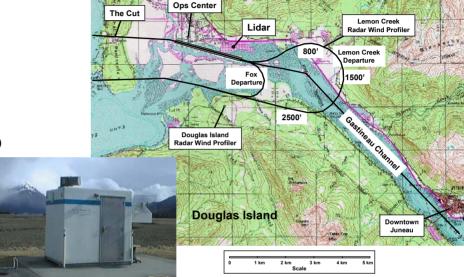
Reflectivity

TDAM 1998 Accomplishments: Lidar

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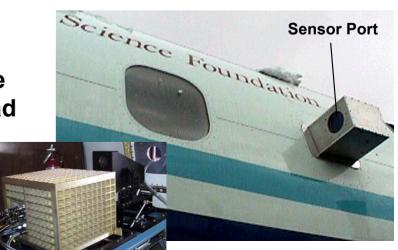
Juneau lidar deployment

- characterization of low altitude windshear and turbulence
- generated validated data sets to support development of lidar turbulence and windshear detection algorithms



ACLAIM/Electra flights

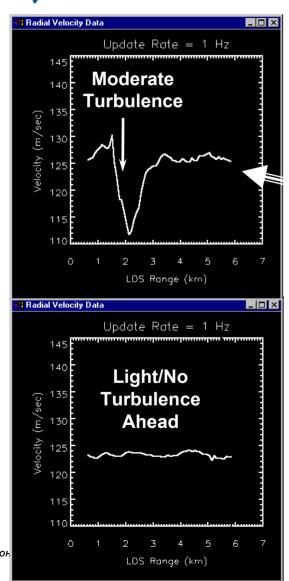
- Detected light to moderate turbulence at ranges between 3 and 6 miles ahead
- Penetrated turbulence to verify
- Operated 15 hours in a variety of conditions from ground to 25kft

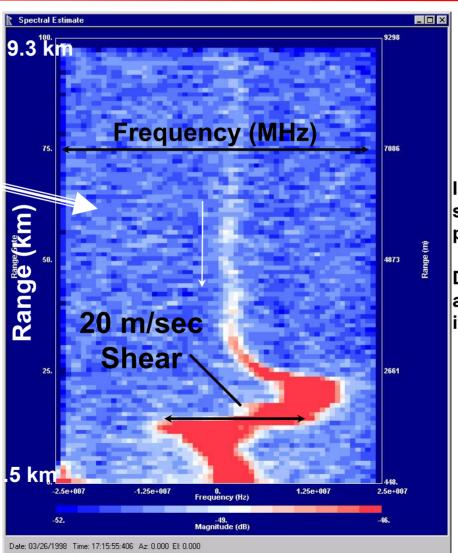


Sample Doppler Spectrum from ACLAIM/Electra



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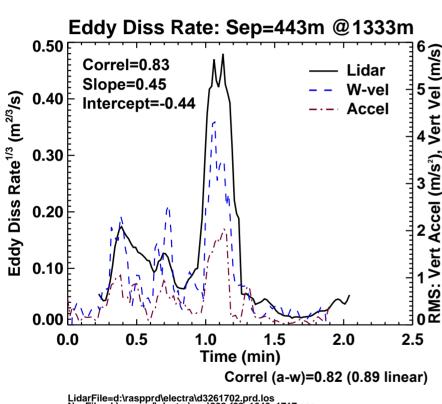
Isolated moderate to severe turbulence patch ahead

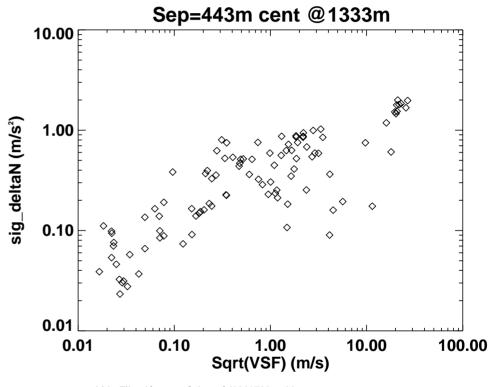
Detected turbulence and later penetrated it for confirmation

Background: Demonstration of Lidar Turbulence Detection

Good Correlation with Onboard Data (Flight 2)







LidarFile=d:\raspprd\electra\d3261702.prd.los
NavFile=d:\raspprd\electra\nav\802rf02 1646 1717.asc
NavFile=d:\raspprd\electra\nav\802rf02 1646 1717.asc
StartTime=1715:05, EndTime=1717:00 IntegWidth= 5.0sec

Correlation of 1.3 km lagged structure function about as good as that between rms acceleration and rms vertical velocity



Industry Consortium Formed in 1999



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<u>Honeywell</u>

- CTI and Honeywell agreement to develop a hybrid turbulence detection system
 - microwave radar combined with infrared radar
 - cover full range of turbulence events
 - additional capability for winds aloft detection (fuel savings)
- United Airlines is critical third member of the team
 - in-kind support, including definition of operational requirements
- Status:
 - CAT IR product development team in place and funded
 - Primary activities are focusing on cost reduction, reliability improvement and flight evaluations

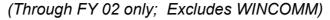
CAT Product Development: Needs



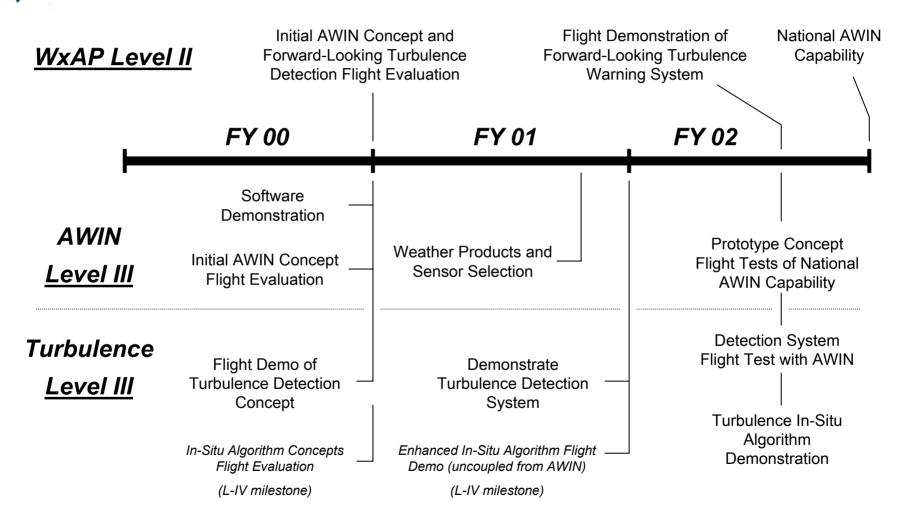
- CAT product development represents a partnership between the CTI/Honeywell/UAL team and NASA AvSP
- Lidar needs are similar to those for microwave radar and include
 - definition and characterization of hazard
 - hazard algorithm for quantifying the threat
 - validated algorithm(s) for using the IR radar to detect and quantify the threat
 - simulation test case development
 - validated system performance with properly designed field tests



SUPPORTED MILESTONES









Program Assets and Resources: Government Agency and Industry



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AFRL System for Precision Air Drop



NASA/ACLAIM System



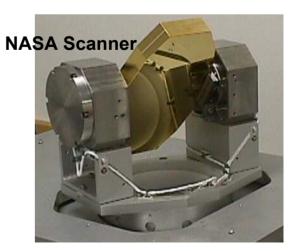


CTI/ARO MAG-1 Transceiver (future)











Flight Testing: Objectives and Needs



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More flight hours at cruise altitudes

- identified as a major gap
- detecting severe turbulence requires a large number of flight hours
- More flight hours in moderate or stronger turbulence
 - mid-level altitudes with focus on convective (storm) and breaking wave turbulence
 - performance envelope for onboard radar and lidar
- Extended data sets for aerosol/turbulence correlation modeling
- Scanning versus single line of sight configuration
 - scanning will enable better characterization of turbulent events
 - more direct comparison with radar for joint tests
 - include a mixture of both modes



FY00/01 Flight Test Objectives



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B-757 flight tests

- joint with other WxAP tests
- primarily focus on convective turbulence
- joint data for post-flight correlation with
 - radar measurements
 - in-situ



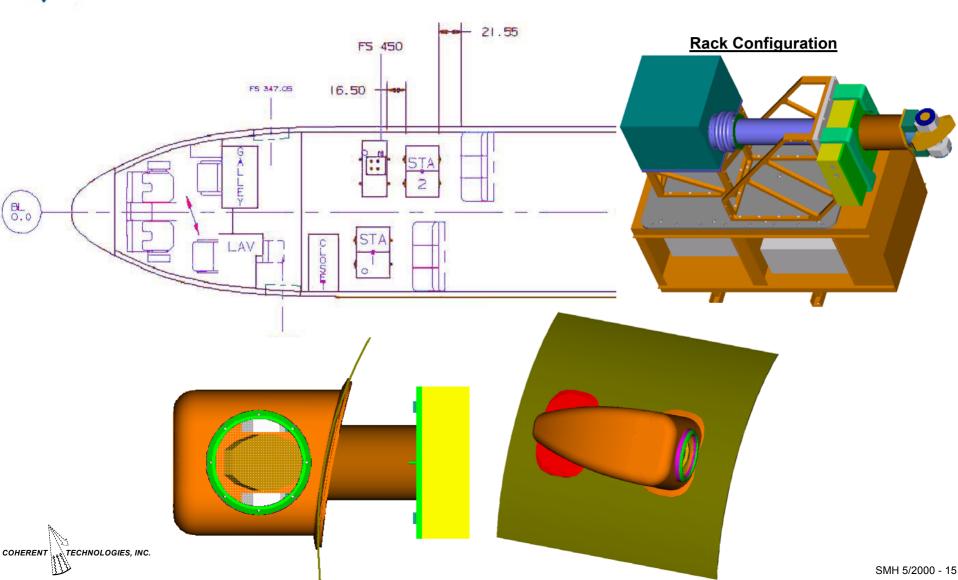
DC-8 flight tests

- lidar operates in a piggy-back fashion
- joint data for post-flight correlation with
 - in-situ
 - aerosol particle measurements
- support lidar performance scaling and algorithm development efforts



B-757 Layout





B-757 Lidar Installation and Flight Test Status/Plans



- NASA SRR held in February
- Lidar installation location has been finalized
- Initial design for fairing and rack assembly
 - design review schedule is being updated
- AFRL equipment at CTI and regular readiness checks will be ongoing until palette installation
- Flights anticipated in early CY01
 - joint with radar

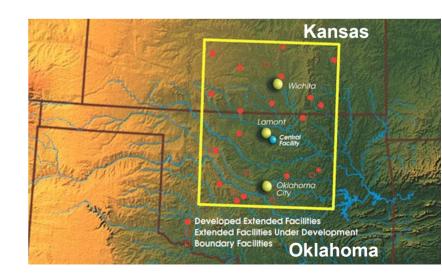


DC-8 Flight Test Status



- DC-8 recent volcanic ash encounter
 - engine replacement required
- Initial flight window (August) dropped
 - Air-Sci program cancelled
- Alternate flight window under evaluation
 - AFWEX DC-8 flights scheduled for December
 - nighttime flights: 40 hrs total
 - evaluating potential conflict with other instrumentation



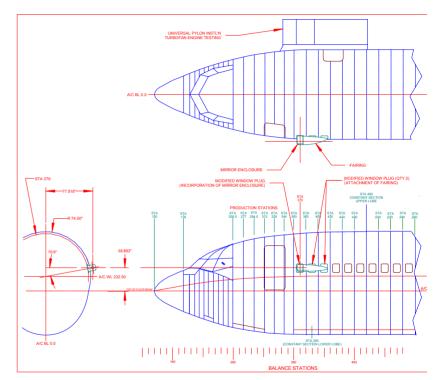




Industry Flight Tests



- Flights aboard Honeywell-owned B-720
- Scheduled for July/August, 2000
 - focus on cruise altitude operation
 - validate performance models
- Future flights...
 - Addition of an RDR-4B windshear radar planned in October, 2000
 - Joint radar/lidar tests in CY01







Lidar Algorithm Development Objective



- Develop reliable detection algorithms for prediction of turbulence hazard ahead using Doppler lidar
 - exploit understanding of unique aspects of lidar phenomenology
 - incorporate common aspects of radar developments



Lidar Algorithm Development and Simulation: Leveraging



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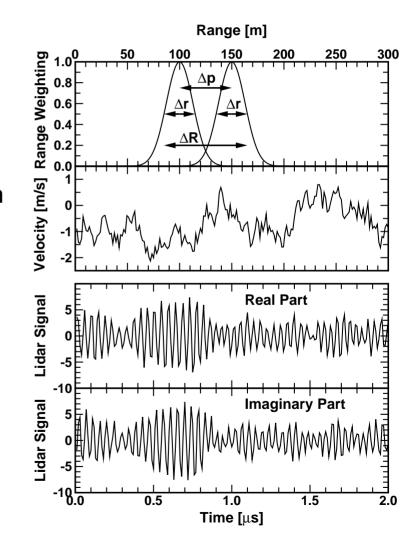
CIRES/NCAR:

- Space Lidar for NASA (SPARCLE)
- extending detailed simulations

• CTI

- simulation for wake vortex detection
- existing real-time algorithms
- Synergy with radar
 - NCAR and RTI developments

Results in cost-effective development with near-term results





Lidar Algorithm and Simulation Activities



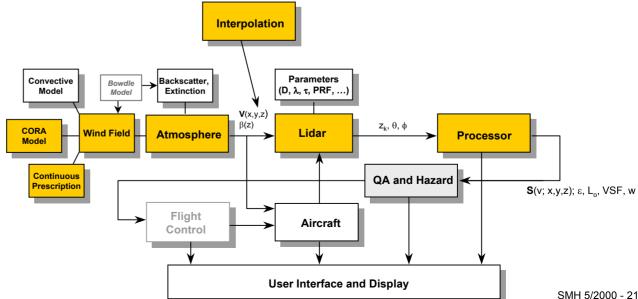
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• FY99/00 Activities/Approach:

- focus on single line of sight algorithms/analyses only and leverage existing tools
- pursue structure function and spectral-width-based algorithms
 - small SNR regime: long range (longer warning times)
 - <u>large SNR regime</u>: correlation of vertical loading with longitudinal observations

 develop <u>preliminary</u> performance predictions based on combination of simulated and flight test data

 truth metrics initially limited (simulation using 2DOF a/c)





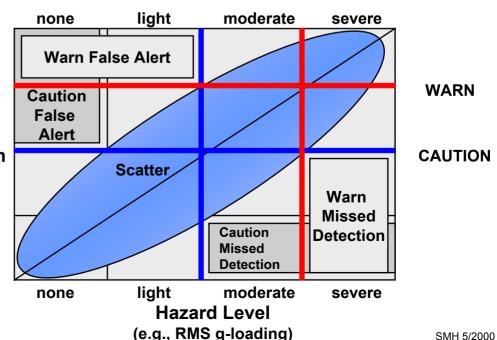
Detection Issues



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- Detection/False Alert must consider the random nature of turbulence
 - multiple turbulence warning levels
 - multiple turbulence classes/types
 - viewing longitudinal velocity behavior and inferring the vertical
- Definition of errors required (not just Type I and Type II)
 - common issue for radar/lidar
 - must minimize scatter

Lidar Observable (Velocity Structure Function or Spectral Width)



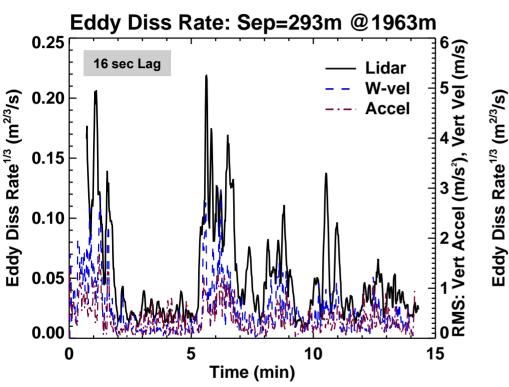


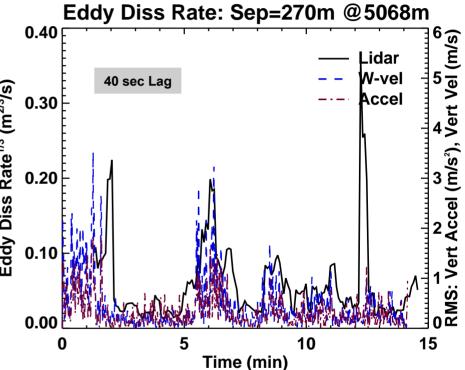
Demonstration of Lidar Turbulence Detection

Good Correlation with Onboard Data out to 40 sec Lag (Flight 2)



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Time Evolution, Beam Pointing
Jitter (A/C Pitch) Can Reduce
Accuracy for Long Lags

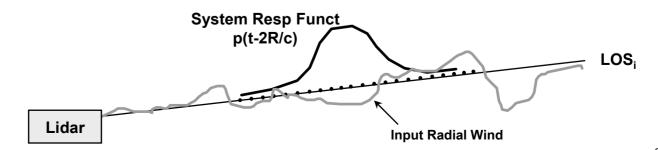
Lidar Algorithm and Simulation: Plans



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• **FY00-02 Approach**:

- maintain synergy with radar algorithm development
- establish SNR requirements and averaging/resolution/performance trade for spectral width and structure function algorithms
- establish link to hazard metric algorithm(s)
- incorporate test cases in more sophisticated simulation
- test on additional data sets (joint lidar/radar test data)
- produce more robust performance predictions and feed back into algo devel
 - false alarm mitigation





Lidar Summary



- Emphasis areas
 - flight testing
 - algorithm development and associated performance analyses
- Flight tests planned for late CY00, early CY01
 - B-757 flights in early CY01, joint with radar
 - piggy-back DC-8 flights uncertain, but may occur in December
 - Industry-funded B-720 flights
- Algorithm work highly leveraged
 - NCAR and CTI developments
 - synergy with radar work (NCAR & RTI)
- Parallel industry program to develop a clear air turbulence product
 - focus is on cost reduction and reliability improvement

